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PROTECTION OF A SPACE VEHICLE THROUGH THE ABSORBTION OF HIGH-ENERGY SPACE PARTICLES

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GROUP 1
Steven Kirschner
Damon Carnes
Richard Funk
Jeff Hall
Jerry Hancock
Kathleen McCarthy
Mike McGuire

NOMENCLATURE

d_{BL} = Ballistic limit thickness

G = Ratio of bumper hole diameter that contributes material to the debris cloud to meteoroid diameter

K = Ratio of mass per unit of the bumper to mass of the meteoroid

R = Ratio of meteoroid kinetic energy to volume of shield material vaporized

Rm = Meteoroid Radius

Rh = Final shield hole radius

Tb = Shield thickness

Uc = Velocity of debris cloud's center of gravity

Um = Meteoroid velocity

Pm = Density of meteoroid material

S = Spacing between strands of mesh

D = Diameter of the strands

Tv = Duration time of voyage in years

N = Number of meteors per square kilometers per year

M = Meteoroid mass, grams

P(0) = probability of no damaging impacts

Pt = density of the bumper material

A = Area of Spacecraft, square kilometers

ABSTRACT

Dual layer meteoroid shields consisting of sacrifical bumper layers spaced some distance outboard from the vehicle hull are the most effective structures yet conceived for protecting space vehicles from hyper-velocity meteoroid impacts. The shield will protect the front of the vehicle. This front area houses the control systems, the life support systems, communications as well as the astronauts. This area is especially vulnerable to impacts normal to its surface at high relative velocities. The cargo area behind the cockpit is partial protected by the fuel tanks. It separated from the cockpit so if a particle penetrates its hull essential life support systems are not dissrupted. This paper presents a new analysis for designing dual-layer shields. The analysis is based upon energy and momentum conservation, as well as the observation of results from extensive experimental impact investigations conducted at velocities ranging from 7 km/s to 30 km/s.

One important conclusion is that most of the kinetic energy of a meteoroid striking a dual layer shield is expended as radiation at the stagnation zone on the primary layer. The analysis includes systematic procedures to evaluate the response of shield designs for a given threat. Similiar applications of the analysis can be used to support a mathematically rigorous procedure for optimum shield design. This idea can be adapted for the concept regarding 'grid' bumpers. The mesh concept offers the reduction of aerial density as

well as the increased advantages of ballistic limit theory. This paper will examine the details of constructing a feasible scheme for protecting a space vehicle from hyper-velocity space particles.

PROBLEM STATEMENT

Protecting a space vehicle from high-speed space particles poses some very complex problems. The relative velocities of these particles are on the order of 70 km/s; if such a particle strikes the hull of the spacecraft, the impact will create serious damage to the craft. This damage can be caused by particles on the order of 100 μm in diameter. The design of a space bumper is thus a crucial concept. Since such particles can not be simply deflected they must be absorbed or broken into pieces so small that they can no longer create any problems.

When designing a space vehicle shield the following problems arise:

1. Geometric Configurations
2. Materials
3. Deployment

The geometry of the shield will not only drastically effect its performance but will also effect its cost. The effect of the space environment on the inherent properties of the materials used must be carefully considered. The problems of deployment will also effect the design.

The problem becomes clearer once a vehicle and what is to be protected on it is specified. The size range, collision probability, and the impact damage of the meteor population can be determined after extensive research. These constraints define the problem so the design process can begin.

MATERIALS

Mylar is a polymer well suited for use as a meteoroid protection shield. Mylar is a registered trademark of the Dupont Corporation for polyethylene terephthalate or PET. For a material to be applicable to long term space use it must be able to withstand the harsh environment of space. This environment has extreme temperatures, very low pressure, and a high flux of ultraviolet and penetrating radiation.

Mylar or PET is a thermoplastic, which means it will melt at some elevated temperature. This property is very important when the material is being considered for use in a space bumper. The striking of a projectile can cause fragments of a space bumper to shear off and have velocities faster then that of the original projectile. This phenomenon is known as spalling. Mylar's melting point is relatively low therefore it will melt or, better yet, vaporize when struck by a high velocity projectile.

Mylar has very good tensile strength. Its tensile strength increases with decreasing temperature like most polymers.

TABLE 1: EFFECTS OF TEMPERATURE ON TENSILE STRENGTH OF MYLAR

TEMPERATURE (°F)	TENSILE STRENGTH (PSI)
390	5,000
77	23,000
-320	39,200

A problem encountered with materials used in space is rapid evaporation in a low pressure environment. The evaporation of a material or a component of that material is greatly hastened by the absence of an atmosphere. This is especially a problem with polymers which have high vapor pressure. But Mylar has a low vapor pressure and does not evaporate quickly. Mylar will lose only 10% of its weight a year at 400°F which is well above its operating temperature range of -423 to 300°F.

The effect of ultraviolet radiation is also critical in the selection of a material to be used in space. Ultraviolet radiation has enough energy to break chemical bonds and initate chemical reactions within the material. Polymers are more suseptible to ultraviolet radiation than metals or ceramics because of their carbon to carbon bonding.

Mylar discolors and embrittles under exposure to ultraviolet radiation. This can be eliminated by coating the Mylar with a very thin film of aluminum. This is known as aluminized Mylar. The aluminum coating absorbs or reflects the ultraviolet radiation leaving the Mylar untouched.

Penetrating radiation can also degrade materials. Mylar has good radiation stabilization characteristics in air and is five times less suseptible in a vacuum.

METEOROID HAZARD

The meteoroid environment poses the greatest hazard to space vehicles especially on missions of long duration. There are three types of meteors: siderites consisting of iron or nickel alloys, aerolites consisting of stony materials, and siderolites consisting of stone and iron. The aerolites form the majority. They are low density "puffballs". The siderites constitute less than 10% of the total meteor population.

The hazard from meteoroid impact is divided into two categories: 1. surface erosion and 2. penetration. The low bulk density particles will cause the surface erosion. They have a low cohesive strength and a low kinetic energy. They fly apart on impact and transmit very little kinetic energy into the surface. This produces very shallow pits. Though this is of major concern with sensitive optical apparatus' surfaces, it is not a safety hazard to the hull of the space ship. Penetration of the hull can cause an explosive decompression of the cabin or at least disruption to vital control or life-support systems.

Design of a space bumper to protect from this hazard requires knowing the probability of collision with various size meteors. Hawkins worked out a relationship between the integrated flux and the mass of the meteor. He found that the smaller meteorite are nearly all stones while the largest are nearly all iron. The variation of the integrated flux with mass developed by Hawkins is shown in figure

7 The cometary meteors are heavier than the micro-meteorites and have a population density that is significant. These meteoroids are believed to be fragments of comets and are loose aggregates of small particles. The following equation gives the integrated flux of these cometry meteoriods:

1. Log N = 0.41 - 1.34 x log M

Figure 8 gives the correlation of velocity with number of meteors. The velocity of meteoroids range from a minimum according to Whipple of 15 km/sec to approximately 75 km/s. The average velocity is about 30 km/s. The mass of the largest meteor that would be expected to impact the space vehicle during its voyage is given by:

2. Log M = 0.306 - 0.747 x log (1 - P(0)) + 0.747 log (A x Tv)

This correlation is shown in figure 9. Langton calculated the time between collisions of various size meteors surface. He found for a meteroid 0.205 inches (5.2 mm) in diameter the time was 38,813 years. For a meteoroid of 0.044 inches (1.118 mm) it was 388 years. The time for a meteoroid of 0.0095 inches (0 242 mm) was 4 years. Therefore meteoroids between 0.1 mm and 1 mm are the most hazardous because of their frequencies.

IMPACT MECHANICS

The muilti-layer meteoroid shield consisting of a thin sacrificial bumper sheet was proposed by Dr. Fred Whipple in 1947. This concept involves the dissipation of energy of potentially dangerous incoming meteoroids by massively disrupting them with the sacrificial sheet. The meteoroid, along with some of the bumper sheet material, is vaporized and sprayed backward such that it impinges upon a much larger surface area than the original meteoroid. The increase in impact area produces a reduction of impact intensity. Some of the meteoroid's energy will also be dissipated in the form of heat. Since the time of Dr. Whipple's proposal many studies have been performed using multi-layer meteoroid shields.

The multi-layer shields have proven, experimentally, to be the most effective meteoroid protection yet conceived. Most experiments have been carried out with velocities in the range of 7 - 10 km/s although some new tests have been performed at velocities up to 30 km/s. Relative velocities in near Earth orbits can be expected to range up to 72 km/s, so many calculations for high velocity or super-velocity (velocity above 30 km/s) impacts are based on theory from extrapolating relatively low velocity experimental data. The theory is based on the theories of conservation of momentum and energy.

The bumper sheet is the first object struck by an incoming meteoroid. Upon impact, shock waves progate forward, in relation to the meteoroid's path, through the bumper material as well as rearward through the meteoroid. Enormous pressures and temperatures are created as the kinetic energy of impact is converted into potential energy of compression. When the shock waves reach the physical boundaries of the bumper shield and the meteoroid, release waves propogate back toward each other and both materials expand violently. The bumper shield works correctly if the meteoroid and the bumper materials, which are now vaporized, form a conical cloud of debris moving in the original direction of the meteoroid. Some material will form a conical cloud moving in the opposite direction, but there is relatively very little mass in this cloud.

If the materials are completely stressed, they will be vaporized. If not, the vapor cloud will also contain liquid droplets or solid particles. The presence of non-vaporized particles indicates that the bumper sheet was not not of correct dimensions for that particular meteoroid mass and velocity due to the wide range of meteoroid sizes and velocities, the presence of liquid and solid particles in the debris cloud can be a common occurence. Certain problems arise from a bumper sheet being both too thin and too thick.

When a meteoroid is larger than the shield was designed to handle, release waves from the distant boundary of the shield propogate faster than the initial shock waves and cause shock wave attenuation which will prevent the vaporization from being completed. This impact situation should be designed out of the shield, using probabilities of large meteoroid impact, since it represents a situation beyond which the vehicle can be expected to survive.

In the case of a meteoroid being smaller than the shield is designed to handle, release waves from the distant boundary of the meteoroid overtake the initial shock waves in the sheet. This causes some of the material to be less than fully shocked. The material will come apart in solid or liquid form depending upon the impacting meteoroid speed. Experimental data shows that spalling occurs for aluminum at a projectile speeds less than 5.6 km/s, and complete vaporization occurs at projectile speeds greater than 10.2 km/s. This data leads to the conclusion that no solid spalled fragments will be traveling faster than 5.6 km/s.

The motion of the debris cloud can be described by a model explained by Swift. The model draws the conclusion that the surface upon which the debris cloud will impinge should be put as far away from the bumper as is possible. This will maximize the surface area upon which the cloud will impinge. Cour-Palais indicates that the benefit from maximizing spacing between the walls of multi-layer meteoroid shields approaches a maximum at 25 to 30 times the diameter of the initial meteoroid. This is due to the vacuum condictions between the sheets in space.

Many experiments have been done using only one sacrificial bumper sheet. These bumpers work excellently over a narrow range test projectils sizes. Over the wide range of meteroid sizes present in space, it becomes necessary to use multiple sheets. Cour-Palais calls the sheets multiple backup sheets, but the intermediate sheets actually act as sacrificial sheets not just as backup sheets. Optimum design for a sheet can only be achieved for a narrow range of impacting particle sizes. A distinct advantage is evident from using multiple sheets in real applications.

Calculations can be made to determine the velocities of particles in the debris cloud, ballistic limits on thickness of bumper sheets, radii of holes formed by the meteoroids, and the angle at which the debris cloud exp'ands. Figure 10 shows all of these properties.

1. $Uc = Um/(1 + (K \times G^2))$

2. $d_{BL} = ((3 \times Rm)/2) \times ((Pm \times Um^2)/R)^{1/3}$

3. $Rh = (4.5 \times 10^{-3}) \times (Rm) \times (Um) \times (Tb/(2 \times Rm))^{2/3} + 0.9 \times Rm$

It should be noted here that these equations are simplified to apply to aluminum bumpers. It assumed that the theory for the sacrificial sheet is the same as for the bumper sheet described by Swift.

Some testing has been done using porous sacrificial sheets. The theory from the solid Whipple bumper can be applied to porous bumpers as long as a conversion is made to equate the weights of the shields. For a given range of meteoriod velocities, shields of equivalent weights provide equivalent protection.

Density of the sacrificial sheet has also been determined to be directly proportional to the amount of damage done to the underlying surfaces. When the ratio of shield weight per unit area to meteoroid weight per unit area is minimized, the damaging contribution from the shield is minimized.

One of the most successful designs for porous sheets has been the grid bumper, consisting of a woven mesh. The advantage of a wire mesh over a solid sheet has proven by examining pressure levels on surfaces lying under the grid bumper. The grid bumper proved to create a 25% lower centerline peak pressure upon impact with the underlying surface and a 62.5% lower pressure 2 inches off the centerline. This indicates that the grid bumper will cause considerably less damage than the solid sacrificial sheet. The pressure pulse also has a longer duration with the grid bumper. This seems to indicate more complete vaporization of the incoming particle. The potential value of the grid bumper is increased by its flexibility and optical properties.

The density of the sacrificial sheet could be decreased further by making the grid out of a less dense material. A soft plastic (such as Mylar) could be used to make up at least part of the wire in the mesh. This would further lower the temperature of vaporization, if combined with aluminum. The velocities which will cause vaporization should then be somewhat below 10.2 km/s, which is beneficial to assure vaporization knowing that near Earth velocities are quite larger.

It should be noted that aluminum and Mylar are good choices when considering ionic properties. The sacrificial sheet must be made out of non-magnetic materials to avoid magnetically charged debris clouds. Such clouds could cause cause problems with communications. It has also been determined that shield strengths are not of critical importance.

DESIGN

The design of this space bumper will consist of three layers of mesh. The first layer will be a woven grid of aluminum coated Mylar designed to pulverize particles up to 1 centimeter diameter. The second (middle) layer will be a woven grid of aluminum. This as a sacrificial grid and is designed to break up any particle that may possibly cause damage to the vehicle. The final grid is designed to vaporize any remaining particle that could cause damage to the ship. This combination will guarantee complete protection for the vehicle.

The aluminum used to coat the Mylar and to construct the middle grid shall be 6061 aluminum. This arrangement of aluminum and Mylar will provide protection comparable to the solid aluminum shield, but it will not generate as much spalling. The thickness of aluminum will vary according to ballistic limit theory calculations. The mesh will be an inter-woven mesh in all three grids. In the first and third grids mesh strands shall be aluminum coated Mylar. The center grid is of all aluminum. Each layer of mesh is seperated from the adjacent layer by highly elastic Mylar springs.

Selection of grid design instead of solid bumper is justified by the following:

1. Debris clouds formed by hyper-velocity impacts with a mesh containing smaller particles will spread over a greater area. Therefore, less damage can be down by post-impact debris.

2. Peak impact pressures (along the centerline of impact) are lower for mesh shields than for solid shields.

3. Strand diameters of mesh bumpers are typically greater than the thickness of comparable solid shields. These larger diameters provide more complete vaporization of hyper-velocity particles.

The application of ballistic limit theory can be used to determine the thickness of the equivalent solid shield.

4. $d_{bl} = ((3 \times Rm)/2) \times ((Um^2 \times Pm)/R)^{1/3}$

Assuming a value of $R = 10^{i}/m$. Thickness of the solid shield should be 1.88 mm (based upon an impact particle of 1 mm traveling at 30 km/s and impacting normal to the surface). For equal protection to be provided by a mesh the weight of the mesh shield should be the same as the weight of the solid bumper. If the diameter of the mesh strands is selected to be the same as the solid shield thickness the mesh spacing can be calculated.

5. $((\pi D^2)/4) \times (1/(S + D)) \times Pt$ = weight of mesh

The spacing of the outer layer was determined to be 0.31 mm.

The second layer is an aluminum mesh (NOTE: There is no Mylar center for this grid) which is designed to pulverize or vaporize any particle (meteoroid or spalled bumper material) striking it. The diameter of the aluminum strands were selected to be 0.01 mm with a mesh spacing of 0.01 mm. This mesh will vaporize when struck by almost any size particle at even low velocity. The energy of impact will almost completely vaporize any particle striking the mesh. The only particles arriving at the third mesh will be post-impact debris.

As determined in hazard analysis the largest particle that can be passed without causing damage to the vehicle is on the order of 0.1 mm. The diameter of the third mesh was selected to be 0.1 mm to prevent any spalled particles from which can do damaging the hull. To prevent passing a particle possible of doing damage the mesh spacing was also selected to be 0.1 mm. From ballistic theory it was calculated that the mest spacing could be as large as 24 mm for a strand diameter of 0.1 mm. By using a mesh spacing of 0.1 mm, the maximum possible protection is guaranteed.

DEPLOYMENT

Mounting the bumper system to the spaceship is a very important aspect of the design. The mounting structure neecs to be rigid so the bumper system will not move around during operation. However, it also needs to be designed to provide ease of fabrication and removal to shorten the time it takes to replace a defective shield.

The foundation structure of the bumper system will be mounted to the ship by a "bayonette" type mounting system. The socket, constructed of titanium, will be recess mounted into the hull of the ship. The sockets will be mounted in a grid pattern one meter apart over the entire surface of the control module. The sockets will be 3.35 centimeters inside diameter, and 5.08 centimeters outside diameter. The socket will be constructed to allow the support column to be pushed down into the socket and rotated 90 degrees. At the bottom of the socket will be a spring to maintain a constant pressure of 3.57 kg/cm to keep the support column pressed firmly into the socket while it is in the locked position.

The support column will be fabricated from schedule 5 aluminum piping. The column is designed to extend 30 centimeters from the surface of the ship. At the bottom of the column will be a roll pin located 2.54 centimeters from the bottom. The pin will be used to keep the column fixed in the socket. The column is pressed down into the socket and then rotated 90 degrees. The spring in the bottom will then push the column up into the locked position.

After the columns are all put into their positions the actual mounting of the bumper sheets begins. The bottom shield will then be applied to the supporting columns by appiying a strong adhesive suitable to the low temperature, high vacuum, and high radiation space environment to the top of the column. The adhesive decided upon was Meltbond 406. It is an epoxy-nylon adhesive designed especially for super-low temperature applications. After the application of the adhesive, the bumper sheet is then fitted to the tops of the columns. At each seam, the sheets will be butt-welded together. After the bottom sheet is put on, Mylar springs will then be applied to the bottom grid. The springs, 30 centimeters tall, 8 centimeters outside diameter, 1 millimeter wire size, and a spring constant 5 /m, will be applied to the bottom bumper sheet with Meltbond 406. The springs will be located in a grid pattern at a spacing of 40 centimeters between centers. After all these springs are set, adhesive will be applied to the top to the springs and the middle bumper sheet put on. The sheet willbe layed over the springs and butt-welded at each seam. Another layer of springs will be put on this middle sheet just like on the bottom sheet. The top will be put on top of these springs with Meltbond 406 used on the bottom sheets. The seams will be butt-welded together and the entire system will then be sealed.

To remove the bumper, the sheets will be sheared apart into small sections. The support columns can then be rotated 90 degrees and popped out. New support columns can be inserted into the sockets and a new bumper system installed.

COST ANALYSIS

The cost of shipping the materials into space is several orders of magnitude larger than the actual cost of the material. Therefore the cost of the material is not taken into account in this analysis.

Given the surface area to be shielded is 930 square meters. The following equation gives the mass per square meter:

$$Pt \times (((\pi \times D^2)/4) \times (1/(S + D))$$

The per cent volume of Mylar to the total volume is 11% and 4% respectively for the outer and the inner mesh. The average density of the mesh is the sum of the density of the aluminum times the per cent aluminum and the density of the Mylar times the per cent of the Mylar. The mass of the outer layer was 5,843,841 kg. The mass of the middle layer was 6,407,700 kg. The mass of the inner layer was 6,202,635 kg. This gives a total weight of 18,454,176 kg.

The masses of the support columns, the sockets, and the springs were found to be neligiable and were ignored. The cost of shipping the material is $3000/lb ($1360/kg), thus the total cost is 25,112 million dollars.

OPERATING INSTRUCTIONS

The lifes of the astronauts as well as the cost of a very expensive space vehicle would be lost if the space bumper should fail and the hull of the ship should be pierced. Therefore extremely stringent rules for inspection need to be implemented.

The shield is designed to withstand particles from 0.01mm to 1 mm in diameter. Meteroids of larger dimensions have a very low flux density. Their size should allow for detection and tracking by radar. Impacts with larger meteoroids can be avoided by moving the space vehicle out of their path.

Periodic inspections should be made of the grid approximatedly every 7,500 hours. These inspections should check for any penetration of the individual grids. Any penetrations should be repaired by placing a patch made of the same size and material as the grid over the hole. The patch should be butt-welded to the bumper grid. The probability of a particle life and in the loss of a multi-million dollar space vehicle makes it imperative that the shield be replaced every third years or if it shows any sign of penetration of the third mesh grid.

OPTIMIZING THE BASIC DESIGN

There have been many different space bumper designs looked at before reaching our final design.

The single wall bumper was the first concept looked at. This design offers the minimum protection fo any shield. This concept uses the ship hull as the protective shield. Because of the low protection this design was quickly dismissed.

The next design considered was a dual wall concept. This is an obvious improvement over the single wall shield. The concept is basically a thin wall in front of the hull of the ship. The shield could be made of various types of metals or other materials. The thickness must be an optimum neither too thick or too thin for reasons discussed earlier. This design was dropped for more advanced concepts.

The dual-wall concept was improved upon by filling the space in between with either a foam or honeycomb of material. This sesign helps to slow meteoroids after they strike the first layer and before they strike the second. The main d drawback to this concept is that the foam or honeycomb transmits the shock wave. The propagation of shock waves to the second layer may generate spalling. Due to this we decided against this concept also.

FAILURE ANALYSIS

The protective space bumper could fail in a number of different ways:

1. There could be a blast failure to the ship due to a debris cloud formed by the shield.

2. There could be perforation of the ship due to spallation of the innermost shield of the bumper. The chance of this has been almost completely eliminated due to the mult-layer shield.

3. There could also be perforation of the ship due to meteoroids passing through open holes in the bumper caused by previous meteoric impact.

4. There could be perforation of the ship due to meteoric impact of a greater size then the shield was designed for. The probabilities of various sizes of meteor were taken into account and the shield was designed to withstand meteors from 0.1 mm to 1 mm which was determined to be the most hazardous. Larger meteoroids are very rare and can be tracked by radar thus can be avoided.

Failure due to multiple impacts at the same point on the shield is the one most likely to occur. The obvious solution to this was careful periodic inspections of the shield and replacement when extensive damage had been done.

CONCLUSIONS AND RECOMMENDATIONS

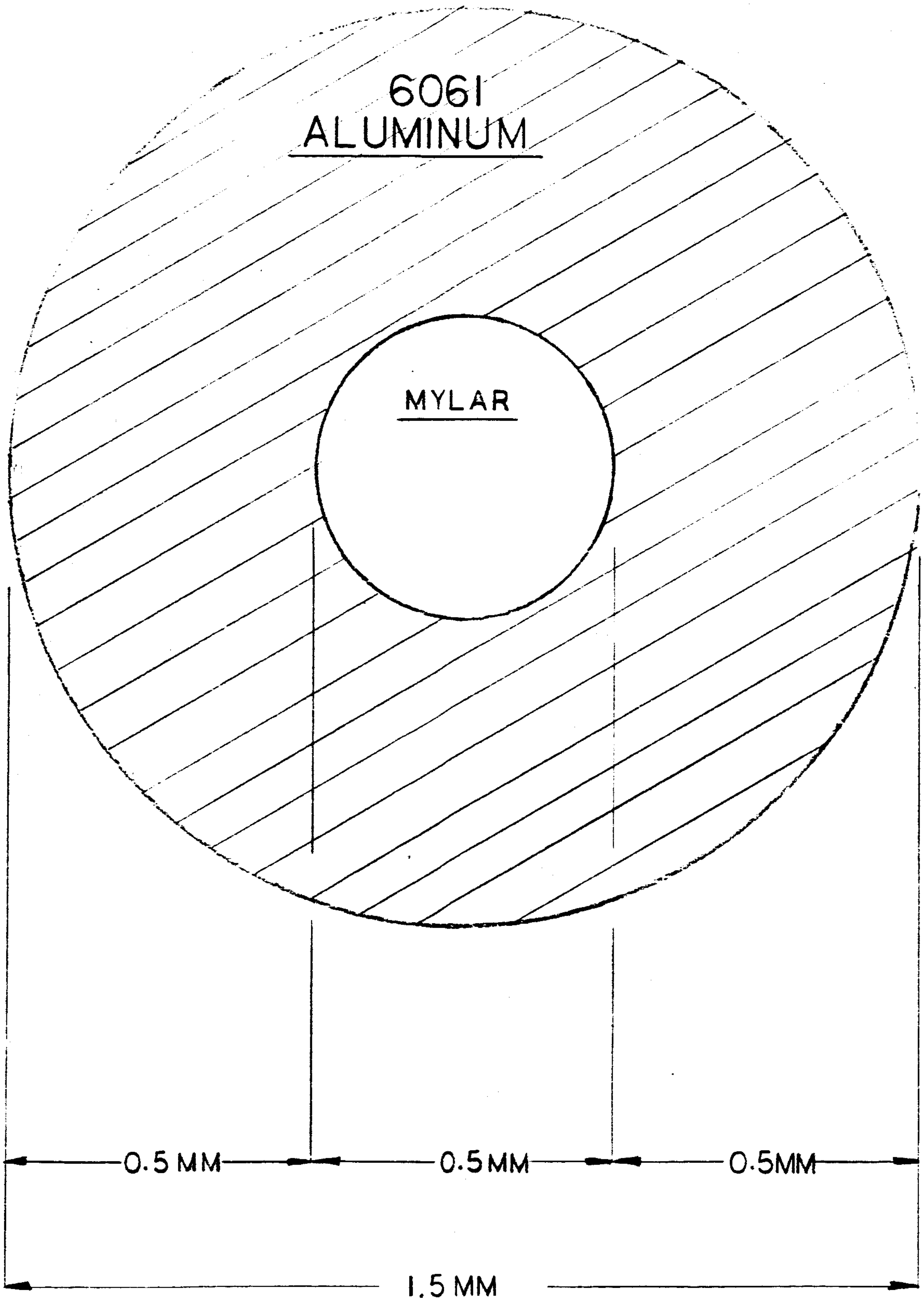
Aluminized Mylar and solid Aluminum were chossen as the most suitable materials for use in a mesh meteoroid shield. Both materials can withstand the harsh environment of space, are inexpensive, and lightweight. Being lightweight reduces the cost of the project since the cost of the shipping is very high.

The use of other materials could be further researched, especially the development of a custom-made alloy. The alloy would have to be able to withstand the harsh space environment, have a high tensile strength, low melting temperature, and have a low density. The establishment of a mining facility on the lunar surfaces would be useful in lowering shipping.

APPENDIX

ALUMINIZED MYLAR
(OUTER LAYER)

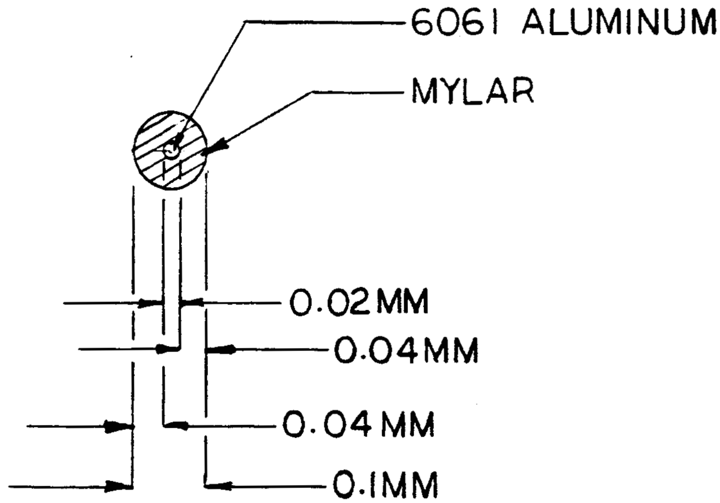
FIG. I



SCALE: 1MM=100MM

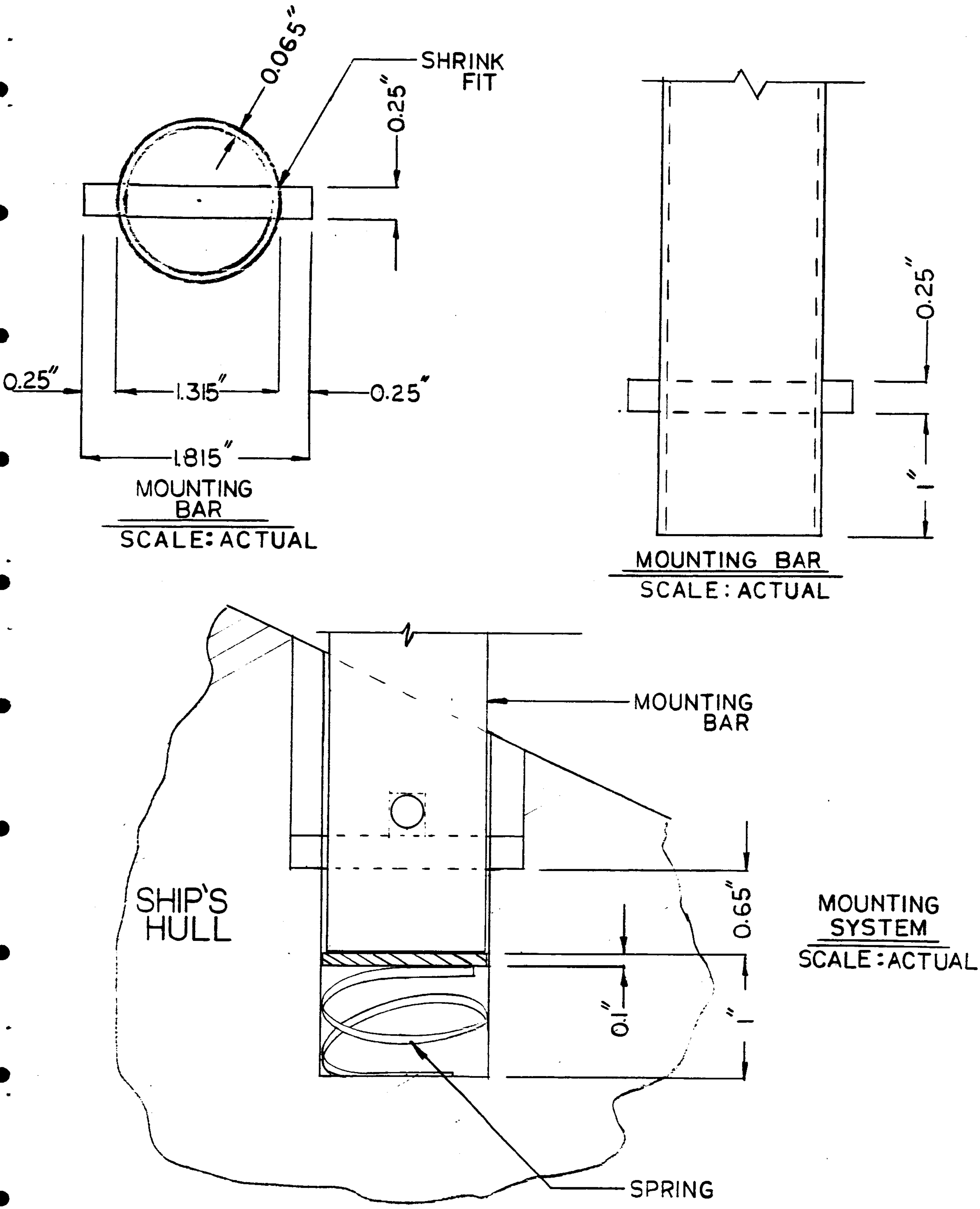
ALUMINIZED MYLAR
(INNER LAYER)

FIG. 2



SCALE: 1 MM = 100MM

FIG. 3


0.065"
SHRINK FIT
0.25"
0.25"
1.315"
0.25"
1.815"
MOUNTING BAR
SCALE: ACTUAL
0.25"
1"
MOUNTING BAR
SCALE: ACTUAL
MOUNTING BAR
SHIP'S HULL
0.65"
0.1"
1"
SPRING
MOUNTING SYSTEM
SCALE: ACTUAL

SHIELD CONFIGURATION

FIG. 4

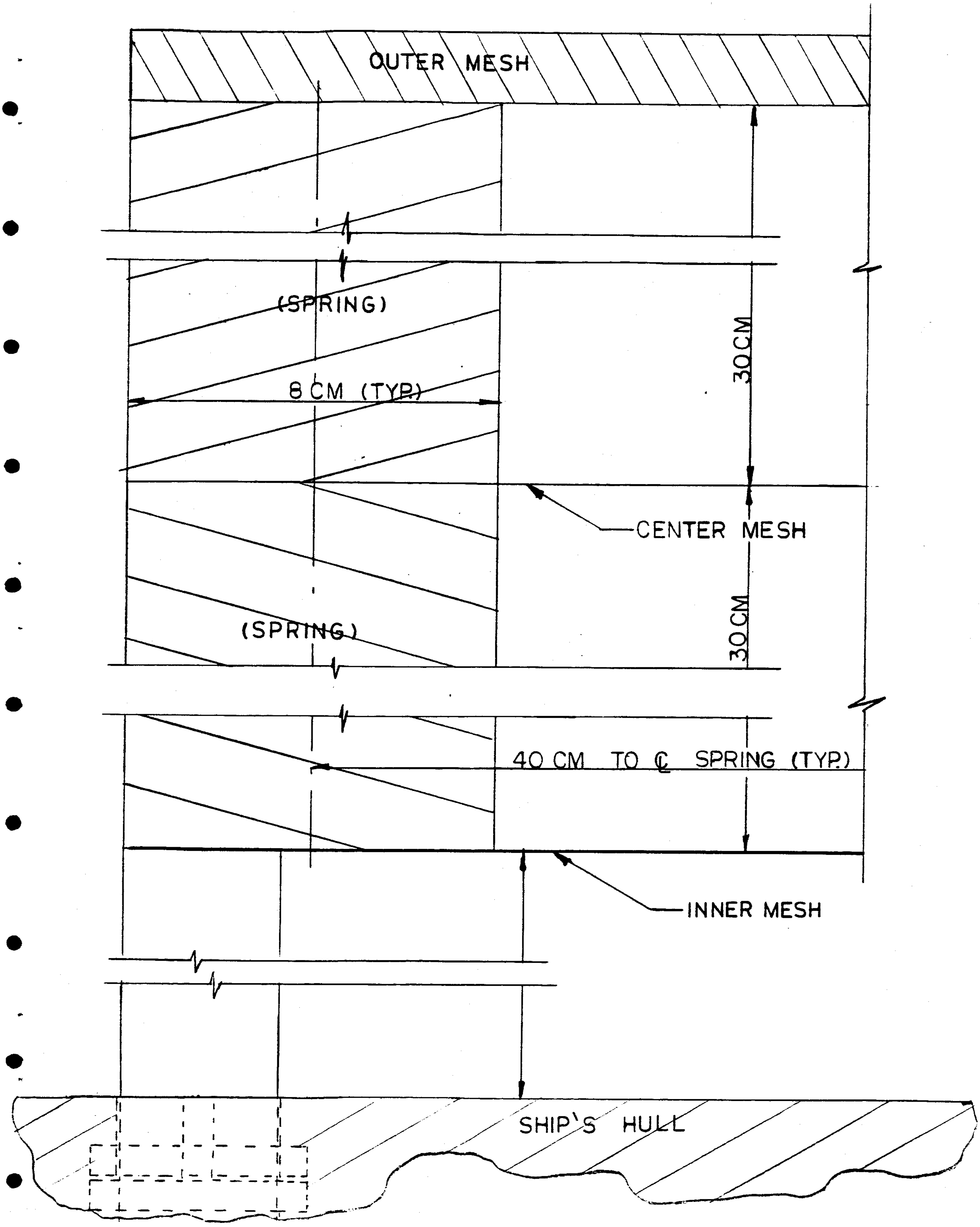


FIG. 5

TYPICAL MESH SECTION:
(INTERWOVEN CONSTRUCTION)

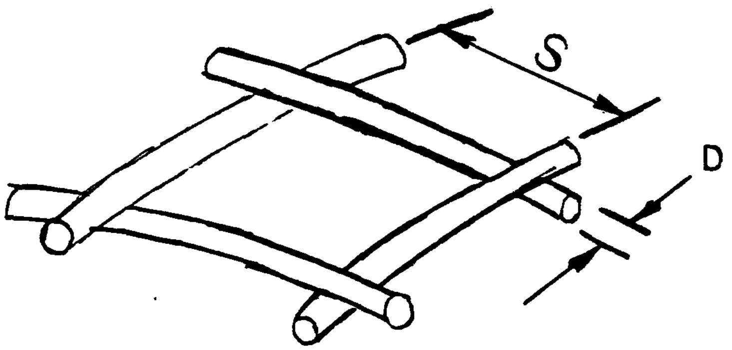


FIG. 6

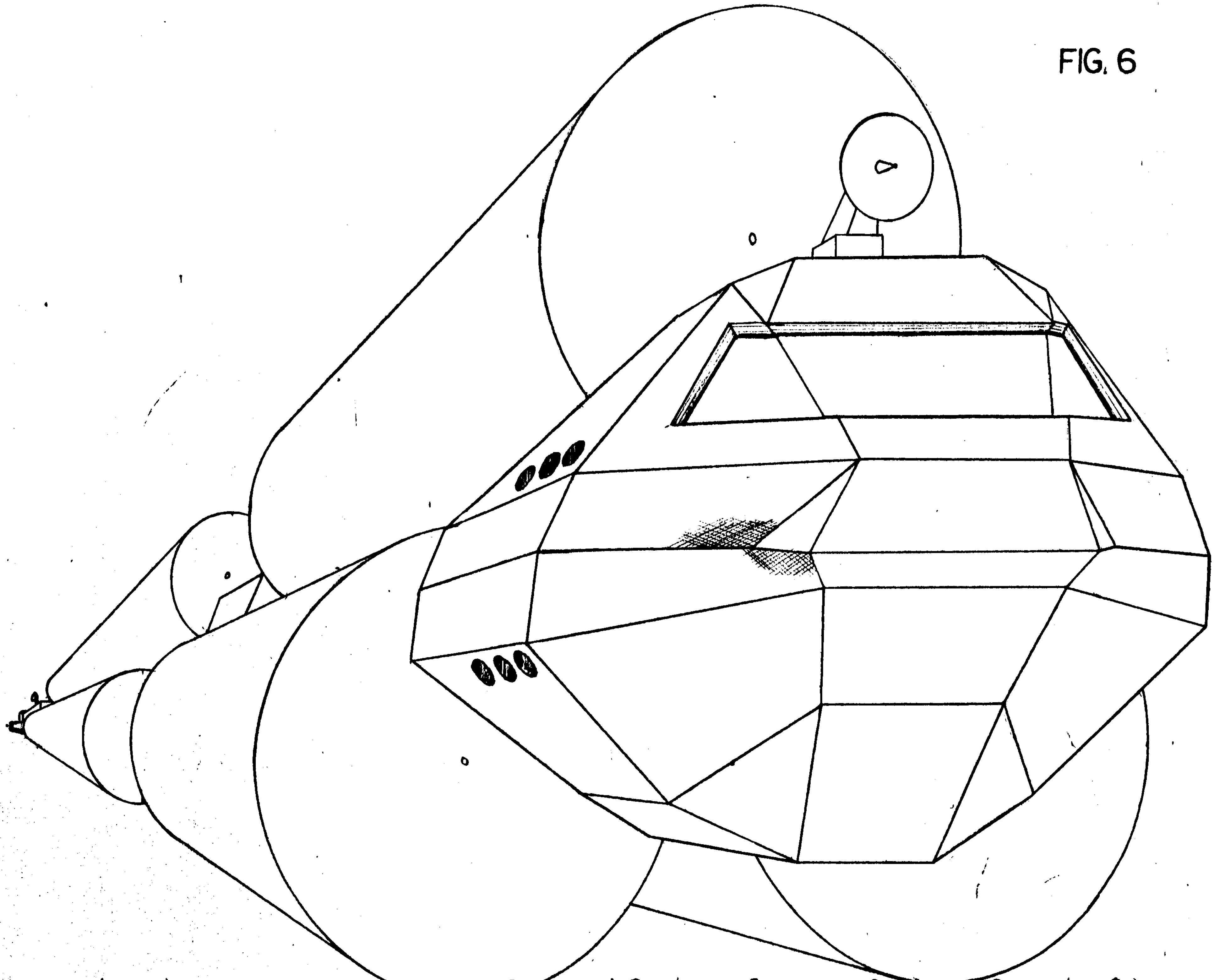
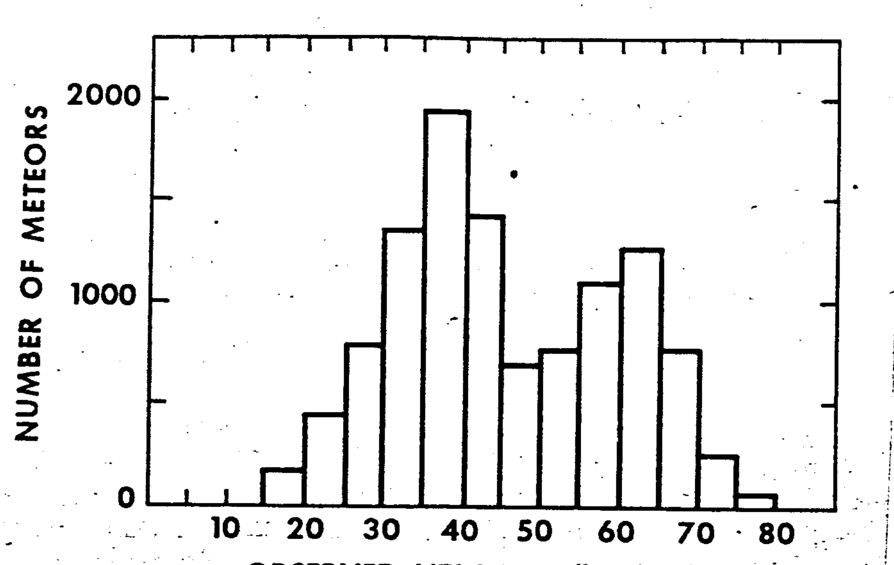
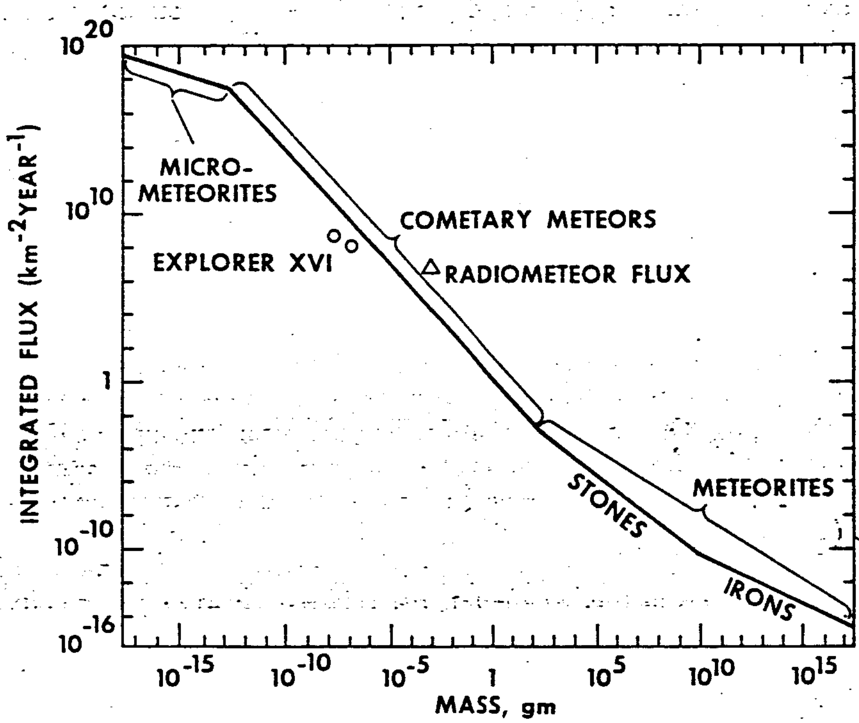


FIGURE #8



McKINLEY VELOCITY DATA

FIGURE # 7



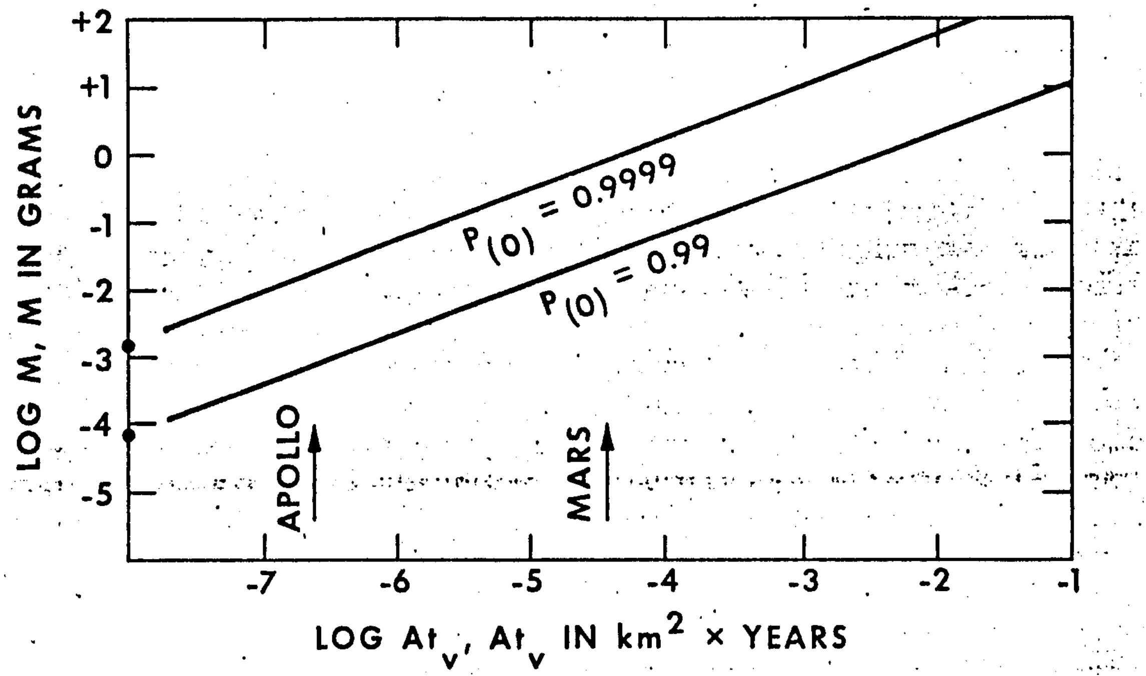

LOG M, M IN GRAMS
+2
+1
0
-1
-2
-3
-4
-5
P(0) = 0.9999
P(0) = 0.99
APOLLO
MARS
-7
-6
-5
-4
-3
-2
-1
LOG Atv', Atv IN km2 × YEARS

FIGURE # 9

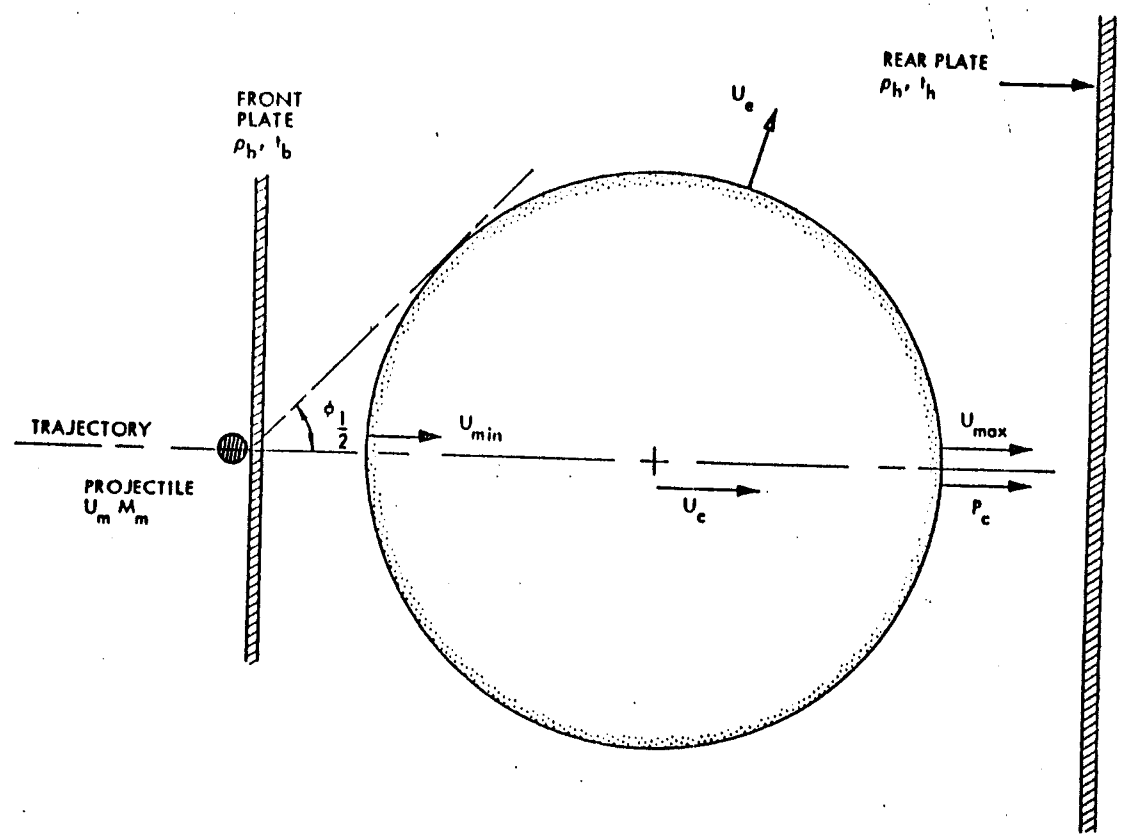


Figure 10. Sketch of Debris Cloud Expanding Behind an Impacted Bumper Presenting Selected Parameters Used in the Analysis.

ME 4182
WEEKLY PROGRESS REPORT

PROJECT TITLE: SPACE VEHICLE BUMPER

TEAM NUMBER: ONE (1) WEEK ENDING: [redacted] OCT. 15,1985

COMMENTS:

We discussed and researched the possible vehicles and areas on this vehicle to protect. After speaking with Aerospace Engineers and Air Force personnel, the decision was made to protect the life support, avionics, communication equipment and crew of the Space Shuttle. Thus, the Space Shuttle's nose and cockpit will be protected from space debris.

PROBLEM STATEMENT: It is necessary to protect the nose and cockpit of the Space Shuttle from space debris to insure the safety of crew, avionics, communication equipment and subsequent flights. The protecttion will be acheived by the absorbtion of non-trackable particles.

TITLE: Protection of Space Shuttle Through the absorbtion of high-speed space particles.

ME 4182
WEEKLY PROGRESS REPORT

PROJECT TITLE: Protection of space vehicle through the absorption of high-energy space partiles.

TEAM NUMBER: ~~ONE(1)~~ WEEK ENDING: 22 OCT 1985

COMMENTS:

We researched particle types (compositions), shower densities of particle storms, and the probabilities of collision. W e also found impact tests for particle velocities ranging from 11,000 to 25,000 feet per second. Particle size is being estimated near the 2cm add smaller diameters due to a lack of reports on radar tracking sensitivity.

Study of possible bumper config urations is also being conducted. Documentation can be found on baffle-type design, although other configurations are being considered. Lunar materials studies from the NASA files were also examined for possible use in the bumper construction.

PROBLEMS:

-Trouble with the on-line data base for G.T. library. Currently down and was not operational until yesterday afternoon.

-Lack of documentation on radar sensitvity. Particle size cannot be accurately determined without these measurements.

*-Unable to locate ASME report format.

ME 4182
WEEKLY PROGRESS REPORT

PROJECT TITLE: Protection of space vehicle through the absorption of high-energy space particles.

TEAM NUMBER: One WEEK ENDING: 29 OCT 1985

COMMENTS:

We utilized the on-line data search in conjuction with Elaine Wagner at the G.T. Library. The results are being mailed from NASA and have not yet arrived.

Our current sources of information are: Journal of Applied Science & Technology, Scientific and Technical Aerospace Reports (STAR), and NASA headings.

We have attempted to contact EE sprcialists in electromagnetism for more information on radar sensitivities.

Status:

Prof. Steffes-	unavailable until 4 Nov.
Prof. Joy-	left word, still waiting to hear from him
Prof. Smith-	not available

Problems: The difficulty in receiving NASA information and radar information.

ME 4182
WEEKLY PROGRESS REPORT

PROJECT TITLE: Protection of space vehicle through the absorbtion of high-energy space particles.

TEAM NUMBER: O N E WEEK ENDING: 5 Nov. 1985

COMMENTS:

We researched several sources which offered different calculations, designs and test data regarding space bumpers. Those sources included The Journal of Spacecraft and Rockets, Spacecraft and Aeronautics, Society of Automotive Engineers Journal, AIAA Journal, NASA journals and lab reports.

We have consolidated our research to include only those designs which have experimental data compiled. The test data shows many favorable conclusions regarding the hypervelocity impact and it's protection. We have data for velocities around 30 Km/sec. The assumptions and theories seem to hold for even higher velocities.

The theories uncovered regarding fragmentation and so-called "cloud formation" eliminated many options and opened the doors of many other options. Thus we have begun our "brainstorming" design process.

ME 4182
WEEKLY PROGRESS REPORT

PROJECT TITLE: Protection of Space Vehicle Through the Absorption of High Energy Space Particles

TEAM NUMBER: 1 WEEK ENDING: 11/12/85

COMMENTS:

This week marked the beginning of the transition from information gathering and research to the production of a final project design. A general outline was set up to aid in the compilation of our report. Also, a tentative schedule was set up consisting of several deadlines to help the group progress smoothly toward a final design and report. The first deadline, which is later this week, will be for the rounding up and circulation of all pertinant information found. A division of duties and responsibilities among the group members was also discussed.

ME 4182
FALL QTR. 1985
TEAM NO. ONE

OUTLINE

TITLE: Protection of Space Vehicle Through the Absorption of High Energy Space Particles

ABSTRACT:

1. From what the space vehicle needs to be protected
2. Why the space vehicle should be protected
3. How the space vehicle will be protected

PROBLEM STATEMENT:

1. Background
    a. Meteor hazard
    b. High velocity impact theory
    c. Dual layer bumper theory
        I. Primary layer
        II. Secondary layer
2. Performance objectives
3. Constraints
    a. Radiation
    b. Communications
    c. Visibility

DETAILED DESCRIPTION:

1. Materials
2. Geometry
3. Mounting to space vehicle
4. Deployment

COST ANALYSIS: Analysis will be dependant upon final design and importance of vehicle protection

HAZARD ANALYSIS:

1. Classification of meteoroid sizes and flux densities
2. Definition of failure
3. Probability of meteoroid impact
4. Deterioration

OPERATING INSTRUCTIONS:

1. Maintenance
2. Replacement

CONCLUSIONS AND RECOMMENDATIONS: Dependant upon final design

APPENDIX:

1. Calculations
2. Drawings
3. Alternatives
4. Decision matrix
5. Progress reports

ME 4182
WEEKLY PROGRESS REPORT

PROJECT TITLE: Protection of Space Vehicle Through the Suppression of ~~High Energy Space Particles~~

TEAM NUMBER: ONE (1) **WEEK ENDING:** 18 NOV 85

COMMENTS:

This week resulted in the culmination of the data collecting process, and the beginning of the actual design and decision-making. Conclusions reached:

The use of an aluminized mylar is the optimum solution, This material will be configured in two (2) sheets of mesh. Currently, we are also examining other combinations and variables: the use of magnesium and its alloys, different mesh opening spacings, different width of twinings.

Today we divided efforts and are preparaing to draft the report.

Sample Calculations

Cost analysis

% mylar = Volume of mylar / Volume of Total material

$\pi \frac{D^2}{4} L$ = Volume of cylinder

Volume mylar = $\pi \frac{(0.5)^2 L}{4}$

Volume Total = $\pi \frac{(1.5)^2 L}{4}$

% mylar = $\left(\frac{\pi (0.5)^2 L}{4}\right)\left(\frac{4}{\pi (1.5)^2 L}\right) = \left(\frac{0.5}{1.5}\right)^2 = 0.11$

Design

$$D = \left(\frac{3 R_m}{2}\right)\left(\frac{U m^2 P_m}{R}\right)^{1/3} = \left(\frac{3\,(0.0005\ m)}{2}\right)\left(\frac{(30{,}000\ m/s)^2 (2200\ \frac{kg}{m^3})}{12.557\,(10^9)\ c/m^3}\right)^{1/3}$$

$= 0.00942\ m$

Weight (solid) = Weight (Grid)

$(2\pi r^2 L)\,\rho_T = \rho_T \left(\frac{\pi D^2}{4}\right)\left(\frac{1}{s+D}\right)$

$2\pi r^2 L = 0.94\ mm^3$

$r^2 = \frac{0.94\ mm^3}{2\pi\,(1\ mm)}$

$r = 0.547\ mm$

$D = 1.1\ mm$

$\left(\frac{\pi D^2}{4}\right)\left(\frac{1}{s+D}\right) = 0.94\ mm^3$

$s = \left[\frac{4\,(0.94\ mm^3)}{\pi\,(1.1\ mm)^2}\right] - 1.1\ mm$

$s = 0.31\ mm.$

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